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Phytotoxicity of Sodium Fluoride and Uptake of Fluoride to Willow Trees

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Intro and scope

Fluoride (F) is present in pristine air, soil and water. As exposure to F through food and beverages is unavoidable, the effects of F on human and mammalian health have been intensely investigated. Due to continued use of super phosphate fertilizers, F accumulates in agricultural soils. However, little is known about the phytotoxicity of sodium fluoride (NaF) and the uptake of F when exposed through roots.

The aim of this study is to:

- 1) Assess the phytotoxicity of NaF to willows when taken up through the roots
- 2) Determine the uptake of F to willows when taken up through roots
- 3) Describe the uptake of F to willows with a non-linear mass balance model

Experimental setup – the willow tree tox test

- 40 cm willow sticks (*Salix viminalis*) were pre-grown and transferred to Erlenmeyer flasks
- Trees were exposed to solutions of various NaF concentrations
- Test duration: 96 h
- Normalized Relative Transpiration (NRT) used as test parameter:

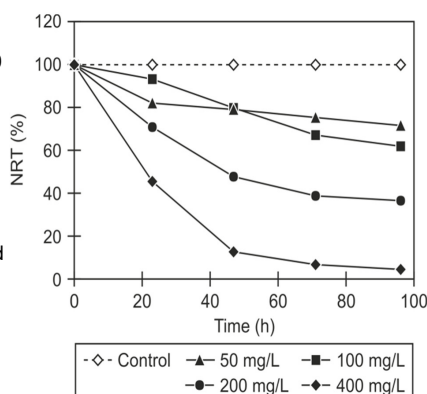
$$NRT(C, t)(\%) = \frac{\frac{1}{n} \sum_{i=1}^n T_i(C, t) / T_i(C, 0)}{\frac{1}{m} \sum_{j=1}^m T_j(0, t) / T_j(0, 0)} \times 100$$

Where,
C) Conc.; t) Time period; T) Abs. transpiration; i and j) Replicate no.;
n) No. of replicates; m) No. of controls see Trapp et al (2008)



Phytotoxicity results

- Toxic effects observed within 48 h for conc. >100 mg F L⁻¹
- Clear dose-response relationship
- No statistically significant difference between toxicity of 50 mg F L⁻¹ and 100 mg F L⁻¹
- Wilting of the trees exposed to 400 mg F L⁻¹



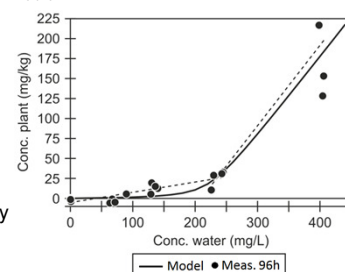
Model description and output

$$0 = \underbrace{\frac{K_M Q C_W}{M_R} + \frac{Q C_W C_R}{M_R}}_{\text{Uptake by transp.}} + \underbrace{\frac{K_M Q C_R}{M_R K_{RW}} - \frac{C_R^2 Q}{M_R K_{RW}}}_{\text{Translocation}} - \underbrace{K_M k_R C_R - k_R C_R^2 - v_{\max} C_R}_{\text{Enzymatic removal}}$$

where,
K_M) Half saturation constant;
Q) Transpiration; C_W) Conc. in external solution; K_R) Mass of roots; C_R) Conc. in roots; K_{RW}) Conc. ratio root/water;
k_R) Root growth rate and v_{max}) Max. enzymatic removal rate see Trapp et al (2008)*

The model assumes:

- Steady state
- Passive uptake of F with the transpiration stream
- Enzymatic removal described by Michaelis-Menten kinetics



Model parameterization

- Maximal enzymatic removal rate, v_{max}: 9 g F kg⁻¹ d⁻¹
- Breakthrough point (BTP): 210 mg F L⁻¹ – On a molar basis the same as obtained by Trapp et al. (2008)* for chloride (Cl)
- Uptake slope approx. 1 for C > BTP – unhindered transport with water

Parameter	Value	Unit	Origin		
Conc. In solution, C_W	0-400	mg L ⁻¹	Measured		
Root mass, m_R	0.001	Kg	Estimated		
Transpiration stream, Q	0.04	L d ⁻¹	Measured ave.		
Half-saturation constant, K_M	2	g L ⁻¹	Fitted		
Max. Enzymatic removal rate, v_{\max}	8.992	g kg ⁻¹ d ⁻¹	Fitted		
Root growth rate, k_R	0	d ⁻¹	Estimated		
	Equation	Valid conc.	R ²	n	P
Regression 1	$y = 0.128x - 5.186$	$C < 209.5$	0.764	16	$<< 0.001$
Regression 2	$y = 1.005x - 210.5$	$C > 209.5$	0.790	8	< 0.005

* Trapp S, Felicova D, Rasmussen N F, Bauer-Gottwein P, 2008, Plant uptake of NaCl in relation to enzyme kinetics and toxic effects, Environ. Exp. Bot., 64, 1-7

Conclusions

- NaF is phytotoxic at levels of EC₁₀: 38.0±34.2; EC₂₀: 59.6±40.7 and EC₅₀: 128±51 (values in mg F L⁻¹ ±95% confidence interval)
- Uptake of F can be described by a non-linear mass balance model assuming enzymatic removal
- At external concentrations above 210 mg F L⁻¹ the willows can no longer pump out F from the plant cells and start to accumulate F
- Enzymatic removal of F and Cl from plant cells is likely to be managed by the same "pump"-system

For more details, see: Lauge PW Clausen, Ulrich G Karlson and Stefan Trapp, 2014, Phytotoxicity of Sodium Fluoride and Uptake of Fluoride to Willow Trees, International Journal of Phytoremediation (In press)

